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A challenging approach for renewable energy market development

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ABSTRACT

This study demonstrates a challenging production-based and market-driven approach for the development of renewable energy (RE) market. The organized data in our research show that the countries that adopt more RE policies appear to generate more RE products. Among those instruments, incentives/subsidies for production are common and decisive to the popularization of RE products.

Recently, the primary RE policy goal for governments is to promote RE products by removing various barriers. However, the energy market should be liberalized as RE products are ubiquitous and able to compete with fossil products. The priority of instruments that governments are supposed to take in order are to remove incentives/subsidies for fossil products, to tax fossil products for the sake of reduction of greenhouse gases emissions, and then, to remove all incentives/subsidies for both fossil and RE products. Furthermore, RE products may have adverse resource and environmental consequences and this dilemma can be averted by taking net energy output as a standard in incentives/subsidies instruments. It was suggested that RE markets are supposed to be classified into three market phases – undeveloped, developing and developed markets. As a promising policy approach, governments have to adopt suitable and flexible instruments to achieve policy goals in different RE market phases.

Contents

1. Introduction

Since the energy crisis in the 1970s, governments have focused on the fossil substituent energy, especially on the renewable energy (RE) such as wind, solar, biomass energy and so forth. Recently, public and private decision makers are considering how to achieve a sustainable transition away from fossil fuel-based energy. Many energy proposals have been executed such as the government research, development for renewable energy technologies, the energy conservation plans, and market driven programs (e.g. regulatory and legislation as well as incentives/subsidies and the carbon tax) [1]. In the meanwhile, numerous local governments are actively planning or implementing RE policies and planning frameworks linked to greenhouse gases emission reduction [2]. However, as far, RE has failed to be a prominent competitor to fossil energy technology since there are significant barriers in implementing RE technologies. These barriers are generally divided into four groups: financial and economic; institutional and political; technical and awareness/information/capacity which are supposed to be conquered in order to develop

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Table 1
The promoting programs for the RE development [3].

Items	Objects	Fiscal incentive tools	Non-fiscal incentive tools
Research, development and demonstration (RD&D)	• Government • Electric producers • Grid producers	• Subsidies for research and development • Capital grants • Third-party finance	• Legislation and international treaties • Research, development and demonstration • Guidelines for energy conservation • Public investment
Investment	• Government • Electric producers • Grid producers	• Capital grants • Bidding system • Subsidies for investment • Third-party finance • Investment tax credits • Accelerated depreciation	• Voluntary programs • Regulatory and administrative rules
Production and distribution	• Electric producers • Grid producers	• Guaranteed Price • Production tax credits • Tradable certificates	• Obligations • Voluntary programs
Consumption	• Government • Consumers	• Consumer grants/rebates • Excise tax exemptions • Net metering • Fossil fuel taxes	• Obligations • Government purchases • Green pricing • Public awareness

innovative policy approaches to release RE potential more efficiently [3]. For example, governments usually adopt various tools, either fiscal or non-fiscal incentive ones, to encourage producers/consumers involved in RE market (see Table 1).

2. Barriers in RE market and policy adoption in the main countries

According to the database of Renewable Energy Policy Network for the 21st Century (REN21) [4], renewable power capacity without considering conventional large hydropower was expanded to 305 GW in 2009 and this is a 90.63% increase versus the capacity of 160 GW in 2004. In addition, countries that have adopted RE policy targets increased to 85 ones until August 2010 (see Fig. 1). Fig. 1 demonstrates that the growth of renewable power capacity is positively related to amount of adopted RE policies.

IEA [5] divided all RE policies into nine groups and half of those (RD&D, financial, incentives/subsidies, public investment, etc.) need fiscal supports from governments. Fig. 2 summaries the adoption of various RE policies in the main countries and reveals that, since 2000, more and more countries are working on the RE

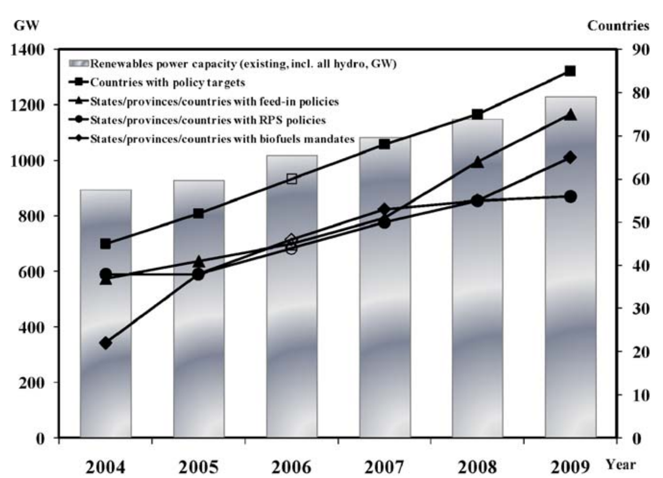

Fig. 1. World's renewable power capacity and countries with financial and economic based RE policy targets (2004–2009) [4]. (a) The country numbers of 2006 are estimated for the data insufficiency. (b) "RSP" stands for "Renewable Portfolio Standards" which places an obligation on energy supply companies to produce a specified fraction of their electricity from renewable energy sources.

policies. Among those, market driven policies including incentives/subsidies, tradable permits and the carbon tax are the popular measures that governments take recently. Therefore, this research presents how to provide a challenging market driven approach to remove the barriers and lead to a dramatic development of sustainable energy market.

3. Basic policy analysis for RE incentives/subsidies

Nowadays, RE market is still limited owing to its two main characteristics-the high production cost and the low energy return on investment compared with conventional fossil energy [6]. Thus, incentives/subsidies are still the most common market driven instruments that governments are taking to facilitate RE market development [7]. Incentives/subsidies have some significant advantages such as: (1) security of energy supply: to ensure adequate domestic energy supply and to reduce import dependency; (2) environmental improvement: to reduce pollution and to fulfill international obligations (e.g. Kyoto Protocol); (3) economic benefits: incentives/subsidies in the form of reduced prices are used to stimulate particular economic sectors or segments of the population (e.g. alleviating poverty and increasing access to energy in developing countries); and (4) employment and social benefits: to maintain employment, especially in periods of economic transition [8]. Recently, security of energy supply and environmental improvement remain the most emphasized RE policy goals [9].

Generally, incentives/subsidies for energy development are defined as a measure taken to reduce energy costs or prices in order to increase the energy production or to accelerate the energy consumption [7]. In other words, the effect of RE incentives/subsidies is to increase RE supply and demand. Owing to the incentives/subsidies, the producer is supposed to be willing to afford RE production and to enter the energy market. Occasionally the government can offer incentives/subsidies to consumers – which are able to boost the market demand. However, this research specifically aimed to the negative effect caused by incentives/subsidies for producers owing to their universal involvement in policy making processes.

In this paper, we use the simplified economic diagrams to demonstrate how incentives/subsidies influence RE supply in three situations – research, development and demonstration (RD&D) instrument adoption, incentives/subsidies instruments adoption as well as the removal of incentives/subsidies for fossil products

	RD & D	Financial	Incentives/ Subsidies	Public Investment	Tradable Permits	Education and Outreach	Policy Processes	Regulatory Instruments	Voluntary Agreement
1976	• DK		• DK					• DK	
		• US						• US	
	• TW								
1980							• DK • JP		
1985	• DE	• DE	• DE				• DE		
	• KR		• KR				• KR		
				• KR					
1990									
								• DE	
			• US						
	• JP		• JP						
						• US			
1995		• DK				• DE			
			• TW • BR	• DE			• CN • BR	• JP	
		• KR							
							• TW • IT		
		• IT	• UK	• BR		• BR			• IT
2000	• US • BR • IT	• UK•TW			• DK • IT	• UK		• UK • IT	• DE • JP
			• TR			• DK • IN		• KR • TR	
	• UK	• CN	• CN • ES • IT		• UK• BR	• UK • JP	• UK • JP		• KR • ES
						• KR • ES • IT	• ES • IL		• BR
					• JP			• IN	
		• IN	• IN • IL				• IN		
2005							• US		
		• ES					• ES	• ES	
	• CN • TR			• US • CN	• US		• TR		• UK • CN
									• TR
	• ES			• DK			• DK • ES	• CN• BR	
				• TW	• ES		• IL	• TW • IL	
2010	• IN• IT	• IN• IT• ES	• IN• IT• UK	• IT			• ES	• IN• ES	
	RD & D	Financial	Incentives/ Subsidies	Public Investment	Tradable Permits	Education and Outreach	Policy Processes	Regulatory Instruments	Voluntary Agreement

Fig. 2. The adoption of various RE policies in the main countries [5]. (a) BR = Brazil, CN = China, DE = Germany, DK = Denmark, IN = India, IT = Italy, IL = Israel, ES = Spain, KR = Korea, JP = Japan, TR = Turkey, TW = Taiwan, UK = United Kingdom, US = United States.

and the carbon tax adoption in the energy market. Our main hypotheses are listed as follows:

- The market price of RE is assumed the same as the price of fossil energy which is determined by the total energy demand.
- The energy market is "perfect competition" – which means that no participants have power to determine the price of a homogeneous energy product.
- The RE cost curves and resource distortion curves are simplified as linear functions.
- The total demand for energy is exogenous and the energy demand curve is linear as well.

The simulation results may have less accuracy based on these hypotheses, however, there are at least two distinct advantages. The first one is that the market conditions used in a system framework can be demonstrated clearly. It bears a resemblance to the concept of basic factors, which gives an overall version of RE market development. The other advantage is that the consistent approach is able to result in a proper assessment on RE market development while comparing to other case studies.

3.1. The RD&D instrument and RE supply

In a virgin RE market, RE products do not exist in the energy market due to high production costs and various barriers as mentioned above. As shown in Fig. 3, there is no intersection between MC_{RE} and P, which means that the producer cannot get costs balanced under the current energy price. Therefore, RE output in the energy market is 0. To establish a new RE market, the government provides a RD&D grant (the shadow area "a", or even more) which encourages the RE producer to enter the energy market and releases new RE products to the public. In this situation, the total RE quantity is denoted as Q_{RE}.

3.2. The incentives/subsidies instruments and RE supply

After the RD&D step, some RE technologies are getting mature. More potential producers are willing to invest in RE products but still hesitate for the revenue uncertainty. Therefore, the government further promotes RE products with incentives/subsidies instruments. Fig. 4 demonstrates that the government takes a guaranteed feed-in tariff instrument (P to P_{FIT}), which is offered in a

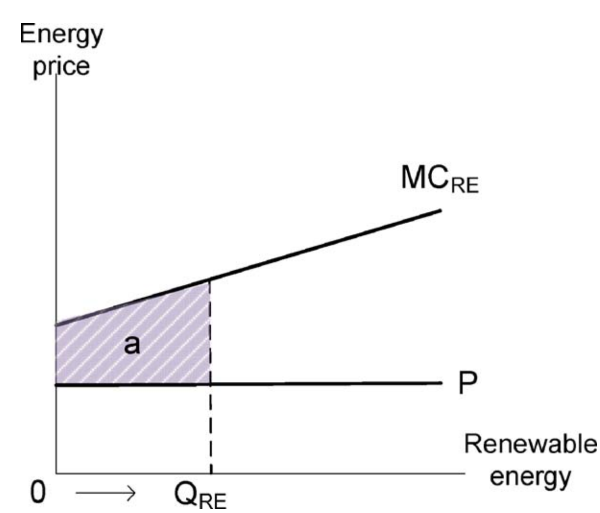

Fig. 3. The RD&D instrument and RE supply.

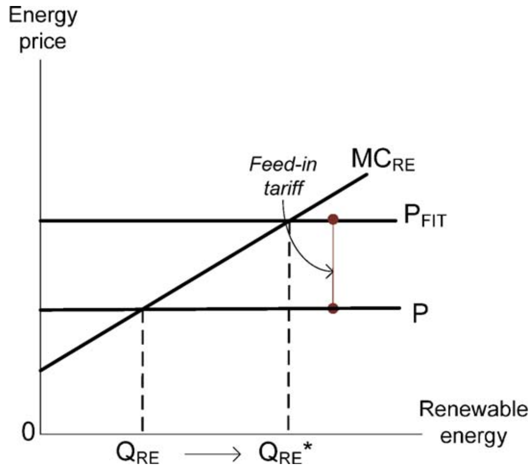

Fig. 4. The incentives/subsidies instruments and RE supply.

non-discriminatory way to all interested producers, to help accelerate the RE supply from Q_{RE} to Q_{RE}*.

3.3. The removal of incentives/subsidies for fossil products and the carbon tax in the energy market

Once RE technologies are well developed and perfectly compete with fossil energy technologies, the energy market is supposed to be liberalized. Based on the perspective of the RE proponents [10,11], the first challenge to reach free market mechanism is to recognize the incentives/subsidies that are built into the supply systems of conventional fuels. Without considering other social impacts, the priorities of economic instruments that governments may take in order are listed as follows:

1. To remove incentives/subsidies for fossil products.
2. To tax fossil products for the sake of reduction of greenhouse gases emissions.
3. To remove all incentives/subsidies for all kinds of energy products, both for fossil and RE ones.

As illustrated in Fig. 5, the removal of incentives/subsidies for fossil products may result in either the fossil cost increase (MC_{F1} to MC_{F2}) or the fossil supply decrease (Q_{F1} to Q_{F2}). In addition, the carbon tax for fossil products further increases the costs of fossil products (MC_{F2} to MC_{F3}) and ends in the quantity decrease gradually (Q_{F2} to Q_{F3}). If $E(D)$ is assumed as the total demand curve for energy, the obtained $E(Q)$ is the total energy equilibrium quantity. Thus, the quantity of fossil substitute products (i.e., RE products) increases to $(E(Q) - Q_{F3})$.

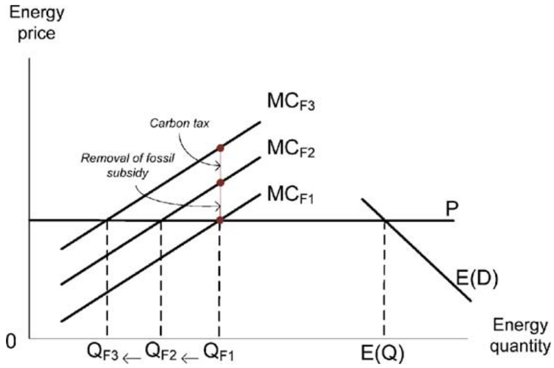

Fig. 5. The removal of incentives/subsidies for fossil products and the carbon tax in the energy market.

3.4. Net energy analysis for the base of incentives/subsidies

One of the purposes of incentives/subsidies is to enhance the energy efficiency contributed by the technology development. However, in certain situations, RE incentives/subsidies which ultimately boast RE production lead to the excessive demand or energy waste by end-users. The arguments over RE incentives/subsidies are emerging in case the implement of incentives/subsidies not only trap governments into fiscal crises but may negatively affect the sustainable development owing to the relatively high fossil energy consumption and waste. In other words, the abuse of incentives/subsidies may cause unrecoverable resource distortion (both fiscal and non-fiscal) which harms the limited resources stock or environment conservation [12–14].

One technique for evaluating energy efficiency is net energy output analysis which is used to compare the amount of energy delivered to the energy market with the total energy required (e.g. to find, extract, process, deliver, and upgrade that energy to a socially useful form). Net energy output is usually achieved by energy acquiring and consumed through life cycle assessment [15]. A basic concept for net energy output is shown as Eq. (1) which shows that the net energy output is defined as the difference between the energy used to harvest an energy source and the amount of energy obtained from that harvest.

$$\mathrm{NEO}_t^* = \sum_{i=1}^{n} \lambda_{i,t} E_{i,t}^{0} - \sum_{i=1}^{n} \lambda_{i,t} E_{i,t}^{C} \tag{1}$$

NEO: net energy output; E^0: energy outputs in thermal equivalents; E^C: energy inputs in thermal equivalents; $\lambda_{i,t}$: energy quality factor for energy type i at time t.

Since the goal of an alternative energy technology is to generate net energy, an ideal energy technology is supposed to exhibit a relatively high net energy output. One of the most ubiquitous measures of process efficiency is the ratio of energy produced to energy consumed for a given technology. This concept is encapsulated by numerous labels and formulations in energy parlance and literature, such as embodied energy [16], net energy [17], net energy gain [18], energy payback [19] and energy return on investment [20–23]. Moreover, Shaw et al. [24–27] demonstrated that incentives/subsidies policy making for RE products

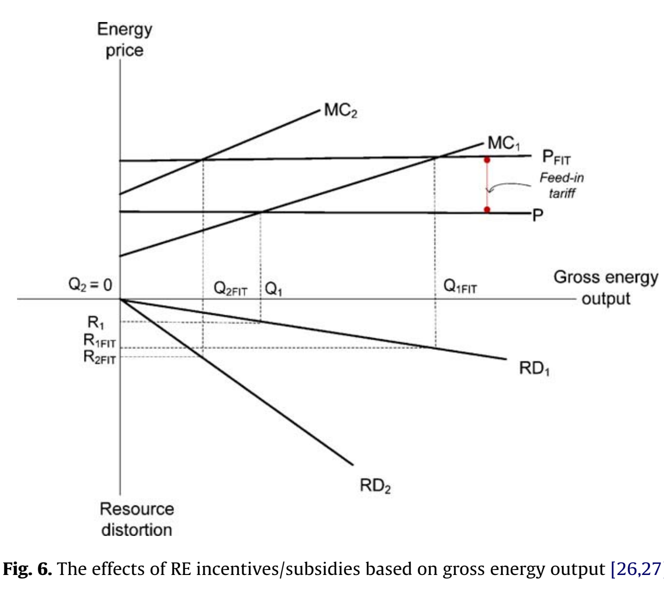

Fig. 6. The effects of RE incentives/subsidies based on gross energy output [26,27].

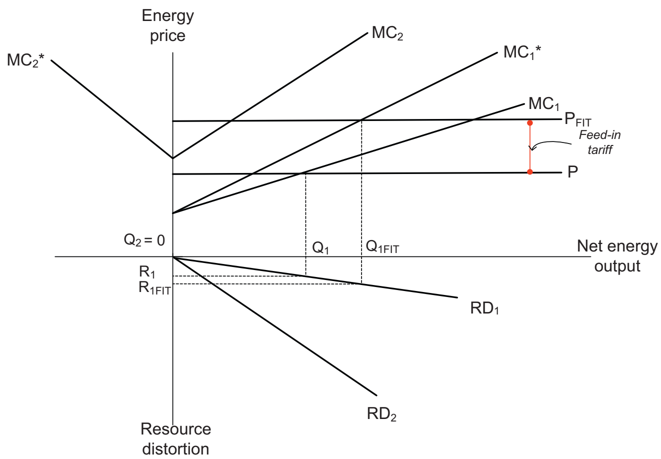

Fig. 7. The effects of RE incentives/subsidies based on net energy output [26,27].

should base on net energy output instead of on gross energy output.

As an ideal policy making process, the basic standards for incentives/subsidies should be as follows:

1. Net energy output >0.
2. {RE costs − RE external benefits (incl. greenhouse gases emission benefits)} < Fossil energy costs (incl. greenhouse gases emission costs).

Here we assume that some kind of resource distortion during RE production occurs since no RE technology is perfect in the real world. In other words, some types of RE products may lead to the negative environmental consequences. This concept is encapsulated by numerous labels and formulations in energy parlance and literatures [21,28–31]. For example, wind turbines are very possible to ruin the aesthetic landscape while chemical fertilizers may be over used in the case of biofuels. Therefore, an ideal RE policy is believed to have a relatively low resource distortion.

Fig. 6 shows two linear marginal cost curves (MC_1 and MC_2) and resources distortion curves (RD_1 and RD_2) of two RE producers. Owing to the different cost curves influenced by the energy efficiency, producers 1 and 2 provide Q_1 and Q_2 (=0) of RE to the energy market, respectively, before the implement of incentives/subsidies policy. If the government adopts incentives/subsidies based on gross energy output, producer 2 will enter the energy market and provide Q_{2FIT} of RE. Although total energy output increases from Q_1 to ($Q_{1FIT} + Q_{2FIT}$) that appears to satisfy the policy goal, resource distortion also increases from R_1 to ($R_{1FIT} + R_{2FIT}$) contemporaneously. In other words, incentives/subsidies are useful as the decision maker attempts to establish a new RE market and to increase the quantity of RE. However, resource distortion also increases without the consideration of the externalities such as CO_2 emissions, energy efficiency waste, etc.

On the other hand, Fig. 7 shows that the two producers have new cost curves, $MC_1{}^*$ and $MC_2{}^*$, based on net energy output. If the government adopts incentives/subsidies based on net energy output, producer 2 may not enter the energy market due to its inefficient technology. Meanwhile, producer 2 has to improve its energy efficiency if it attempts to enter the energy market. As a result, resource distortion R_{1FIT} is less than ($R_{1FIT} + R_{2FIT}$) despite the total energy output provided to the energy market increases slowly (Fig. 6). This result reveals that the resources distortion, which is caused by putting gross energy output as a standard, can be exempted in case the net energy output standard is taken.

Table 2 summarizes the comparison between incentives/subsidies based on different objectives and net energy outputs. Capacity or gross energy output standards ensure adequate energy supply but are difficult to impose external costs. However, energy policies have to be carried out in a world of uncertainty. Currently, RE technologies are usually in its infancy and this stifles the fulfillment of energy efficiency analysis. Governments do neither know exactly what resources are being used by each energy technology in their life cycles nor exactly what their net energy outputs are. Net energy output standard may put governments into

Table 2
The comparison between incentives/subsidies based on different objectives- capacity, gross energy output and net energy output.

	Capacity	Gross energy output	Net energy output
Impact factor	Installed capacity	Capacity factor (%)	Net output factor (%)
Objective step	RD&D; investment	Production	Production
Classification	Quota system	Price system	Price system
Instruments	RD&D grant; tradable permits	Financial supports; incentives/subsidies	
Advantages	• Ensure adequate domestic energy supply • The policy effects are visible to the public • Low cost projects can also be encouraged • Smaller government fiscal load	• Ensure adequate domestic energy supply • Feed-in tariffs are flexible with technology improvement and district needs	• Modify financial system to encourage efficiency innovation • Keep inefficient producers from the energy market • Reduce pollution, including different emissions and to fulfill international obligations •internalize external costs
Weakness	• The optimal output goal cannot be exactly estimated • Some energy subsidies may counter the goal of environmental and energy sustainable and cause more resources wasted • Higher risk and lower return impede producers from R&D • Only focus on "major" technologies and resource-abundant regions • The adoption of tradable permits causes high transaction costs • Failure to impose external costs	• Inefficient producers which cause more resource wasted can also enter the energy market • Failure to impose external costs	• Only focus on "major" players: high technical, and financial are barriers for small-sized projects • Local energy producers are handicapped • High administrative costs for life cycle energy balance database

Table 3
The goals and energy instruments in different RE market phases.

Phases	1. Undeveloped market	2. Developing market		3. Developed market
Steps	R&D, investment	Production	Consumption	Production, consumption
Goals	To establish RE market	To improve the production of RE	To improve the consumption of RE	• To replace fossil energy by RE • To return to the free market mechanism
Non-market based policies	Regulatory instruments Policy processes Voluntary agreement Education and outreach			
Market based policies	RD&D	Financial Incentives/subsidies Tradable permits	Financial Public Investment	Liberalization
Specific applications	• R&D grants and subsidies • Demonstration	• Investment deduction • Tax credit • Accelerated depreciation • Guaranteed price • Obligations and tradable permits	• Tax incentives • Grants and subsidies • Public investment	• Removal of the fossil energy subsidies • Carbon tax • Green pricing • Removal of RE incentives/ subsidies
Mechanisms	Quota system	Quota system, price system	Price system	Free market system

a high administrative cost risk for establishing the life cycle energy balance database for all energy technologies.

4. Discussions: a flexible system in different RE development phases

It has been argued that RE technologies "can't compete on price without public incentives/subsidies" [32]. However, the history of coal, oil, natural gas, and even nuclear power market shows that fossil energy also developed with incentives/subsidies [33,34]. For considering the present energy policy, governments are suggested to expand more RE products into the energy market. Also, it is crucial to establish a flexible system in compliance with different RE development conditions.

The RE development is proposed to be classified into three market phases – undeveloped, developing and developed markets. Governments are suggested to adopt suitable and flexible instruments to achieve policy goals in different market phases. In an undeveloped RE market, few RE products are in the energy market and RE policy goal is to establish a new RE market and to heave the public awareness of the RE products. Governments are suggested to exploit RD&D and provide favorable grants to encourage potential producers. So far, tidal and geothermal markets are the well instances.

In a developing RE market, some RE products exist in the energy market but are still incapable of competing with fossil energy products. Therefore, the RE governments should provide favorable incentives/subsidies such as investment subsidies, investment tax credit, tax incentives and public investment, etc., which encourage potential producers to enter the RE market. In addition, RE policy should also aim at how to support a complicated RE system with legislation, policy processes, RE marketing systems, public awareness improvement, etc.

In a developed RE market, RE products are ubiquitous in the energy market and consumers are familiar with them as an alternative energy. Therefore, governments have to liberalize the energy market to avoid any various distortion caused by the stiff consideration of energy security or market stability. Governments are supposed to remove incentives/subsidies for fossil products. Furthermore, governments can tax fossil products for the sake of environmental conservation. As an optimal energy policy, governments should remove all kinds of incentives/subsidies built into energy products, both for fossil and RE ones, to accomplish a real liberalized energy market.

Table 3 demonstrates the goals and energy policies in different RE market phases. Nowadays, most RE markets around the world are in the developing RE market and some governments adopting carbon tax are stepping into a developed one. In fact, the ultimate goal of energy policies is to accomplish a real free energy market in which RE and fossil energy can perfectly compete with each other without any artificial interference and distortions.

5. Conclusions

This paper provides a challenging production-based and market-driven approach for RE market development to achieve an optimal energy market. From these expositions, some critical conclusions are listed as follows:

- Based on the policy adoptions in the main countries, the growth of RE capacity is positively relevant to the growth of RE policy adoptions. That is, the more RE policies countries adopt, the more RE capacity countries can achieve. Market-driven policies such as incentives/subsidies for RE products are recently believed to be conducive and detrimental to popularize RE products.
- If RE technologies are ubiquitous and perfectly compete with fossil energy technologies, the energy market should be liberalized and back to e a free market mechanism. Without considering other social impacts, the principled economic instruments for governments to adopt are:

1. To remove incentives/subsidies for fossil products.
2. To tax fossil products for the sake of reduction of greenhouse gases emissions.
3. To remove all incentives/subsidies for all kinds of energy products, both fossil and RE ones.

- Some types of RE may have adverse resource and environmental outcomes. Therefore, an ideal RE policy is believed to have a relatively low resource distortions. The adoption of net energy output standard incentives/subsidies is able to promise less resource distortions such as energy waste or negative environmental effects caused by gross energy output standard. Nevertheless, net energy output standard may lead to a high administrative cost for establishing a database of life cycle energy balance for all energy technologies.
- Governments are suggested to set up a flexible system in compliance with different RE development conditions. The RE development can be classified into three market phases – undeveloped, developing and developed markets. As an optimal

policy approach, governments are supposed to adopt suitable and flexible instruments to achieve policy goals in different market phases.

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